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VOLUME 9 NUMBER 6

AUGUST, 1919

Phytopathology

Official Organ of the American Phytopathological Society

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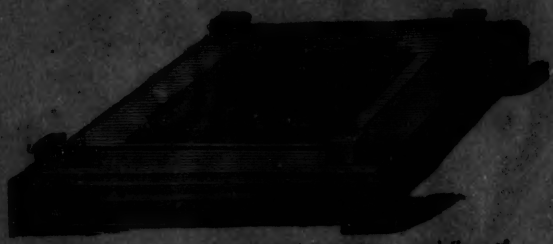
PUBLISHED MONTHLY FOR THE SOCIETY

OFFICE OF PUBLICATION

2419-21 Greenmount Ave., Baltimore, Md.

Entered as second-class matter May 16, 1913, at the post office at Baltimore, Maryland, under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917. Authorized on July 2, 1918.

Price { $5.00 per year, United States and dependencies, Mexico and Cuba
$5.25 per year, Canada
$5.50 per year, elsewhere



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PHYTOPATHOLOGY

VOLUME IX NUMBER 8

AUGUST 1919

BIOLOGIC FORMS OF PUCCINIA CORONATA ON OATS[1]

G. R. HOERNER

WITH PLATES XIX AND XX

Recent work (1, 2, 4, 5, 6, 7) has shown that varieties of wheat may act as differential hosts in establishing the identity of biologic forms of *Puccinia graminis* Pers. This discovery of biologic specialization of *Puccinia graminis* within the genus Triticum suggested the possibility of similar specialization of *Puccinia coronata* Cda[2] within the genus Avena.

About two years ago the writer began an extensive investigation to determine the infection capabilities of crown rust of oats. Inoculations were made with stock cultures of rust originally obtained from Lynchburg, Va., San Diego, Cal., Tallulah, La., and University Farm, St. Paul, Minn.

Fifty-five species, belonging to twenty-six genera of cereals and wild and cultivated grasses, were inoculated with the rust from these four sources in order to distinguish, if possible, biologic forms of the crown rust on grasses.

The rust collected on oats from these different sections of the United States did not exhibit the same infection capabilities, but the differences were neither definite nor consistent enough to enable the writer to distinguish distinct biologic forms by means of their action on grasses. Inoculations were made to ascertain whether varieties of oats commonly grown in the general region from which a particular specimen of crown rust was obtained would be more susceptible or resistant to the rust from that

[1] Published with the approval of the Director, as Paper No. 151 of the Journal Series of the Minnesota Agricultural Experiment Station.

The writer wishes to acknowledge the assistance given him by many pathologists who furnished rust material for inoculation purposes and to Dr. I. E. Melhus who kindly supplied the seed of the Iowa oat selections.

[2] There is some confusion in the nomenclature of this rust. In this paper it has been considered advisable to use the name *Puccinia coronata* Cda. (= *P. lolii* Niels = *P. coronifera* Kleb).

locality than to the rust from the other three localities. The results of these inoculations are given in table 1. The varieties and strains of oats inoculated are listed under the state in which they were grown. The numbers are those of the State Station under which the varieties are listed.

TABLE 1

Results of inoculating varieties and strains of oats with Puccinia coronata from different regions

VARIETIES AND STRAINS OF OATS INOCULATED	PLACE OF COLLECTION OF RUST	
	Tallulah, La.	St. Paul, Minn.
	Character of infection	
Alabama		
Appler 617	Susceptible	Resistant
Burt—Spring strain	Susceptible	Resistant
Fulghum 313	Susceptible	Susceptible
Red Rust Proof—Spring strain	Susceptible	Susceptible
California		
Oklahoma Red Rust Proof	Susceptible	Susceptible
Texas Red Rust Proof	Susceptible	Susceptible
Iowa		
Green Russian 96	Resistant	Resistant
Ruakura Rust Proof 73	Resistant	Resistant
White Russian 101½	Resistant	Resistant
White Russian 102½	Resistant	Resistant
103 (Minnesota 531)	Susceptible	Susceptible
115	Susceptible	Susceptible
Minnesota		
Bully Good 512	Susceptible	Susceptible
Golden Rain 528	Susceptible	Susceptible
Improved Ligowa 281	Susceptible	Susceptible
Joonette 550	Susceptible	Susceptible
Red Rust Proof 538	Susceptible	Susceptible
Silver Mine 506	Susceptible	Susceptible
Sixty Day 261	Susceptible	Susceptible
Swedish Crown 526	Susceptible	Susceptible
Victory 514	Susceptible	Susceptible
White Russian 339	Susceptible	Susceptible
Virginia		
Burt	Susceptible	Susceptible
Swedish Select	Susceptible	Susceptible
Texas Red Rust Proof	Susceptible	Susceptible

The fact that certain of the varieties and strains of oats listed in table 1 showed some signs of resistance led the writer to believe that they might act as differential hosts and make it possible to distinguish biologic forms

of crown rust by means of their action on varieties of oats just as certain wheat varieties acting as differential hosts have made possible the recognition of several biologic forms of *Puccinia graminis* Pers. on wheat (5).

It was impossible to obtain additional seed of the resistant Alabama oats and the following selections were therefore used: Green Russian (Iowa 96), Ruakura Rust Proof (Iowa 73), White Russian (Iowa 101½ and 102½, Iowa 115). The varieties Iowa 103 (Minnesota 531) and Improved Ligowa (Minnesota 281) were used as checks.[4] These seven oat varieties were inoculated with crown rust of oats obtained from thirty localities in nineteen different states, the District of Columbia and the Province of Quebec, Canada.

The methods employed in making inoculations were similar to those described by Stakman and Piemeisel (7). The results are given in table 2.

It is evident from the behavior of Ruakura Rust Proof (Iowa 73) and Green Russian (Iowa 96) that there are several distinct biologic forms of crown rust on varieties of oats. The character of infection on these two varieties was distinct and consistent. The work with the other strains of oats was preliminary and therefore their reaction to the various strains of rust employed has not been used as a basis for identifying biologic forms.

As shown in tables 1 and 2, the reaction of the varieties and strains of oats inoculated with the various strains of rust varied considerably. Iowa 115, Iowa 103 (Minnesota 531), and Improved Ligowa (Minnesota 281) were generally susceptible to all the strains of rust used. White Russian (Iowa 101½ and 102½) showed signs of varying degrees of susceptibility, but the most striking differences occurred in the case of Ruakura Rust Proof (Iowa 73) and Green Russian (Iowa 96). These two varilogic proved to be differential hosts, making it possible to identify bioetics forms of *Puccinia coronata*.

Every strain[5] of rust employed did not represent a distinct biologic form. Several strains of rust acted the same on the two differential hosts. For example Iowa 73 and Iowa 96 were both heavily infected by the rust collected on *Avena sativa* at Clemson College, S. C., Jackson, Tenn., and Tallulah, La. The rust collected on Rhamnus at Burlington, Vt., and that collected on *Avena sativa* at Auburn, Ala., infected these two oat varieties only very lightly. The rust collected on Rhamnus at St. Paul, Minn., and on *Avena sativa* at Waseca, Minn., and Washington, D. C. infected Iowa 73 very weakly but infected Iowa 96 heavily. Iowa 73 was heavily infected by the rust collected on *Avena sativa* at Marion, Ohio, but Iowa 96 was but lightly infected (see plates XIX and XX.)

[5] The term "strain" is used to indicate merely a locality collection.

Four distinct biologic forms of rust can, therefore, be distinguished on the basis of their action on Ruakura Rust Proof (Iowa 73) and Green Russian (Iowa 96). The action of these forms on these selections can be summarized as follows (see plates XIX and XX):

Form 1. Infects both Iowa 73 and Iowa 96 normally.

Form 2. Infects both varieties weakly.

Form 3. Infects Iowa 73 weakly but infects Iowa 96 normally.

Form 4. Infects Iowa 73 normally but infects Iowa 96 weakly.

When the action of more rust strains on many more hosts than the seven oat varieties here considered has been observed, it may be possible to identify a greater number of biologic forms of the rust than the four here reported. This is a question that can be settled only by further and more intensive work.

It has been suggested that the production of a purple pigment and the early development of telia on oat varieties indicated resistance to rust (3). Purple pigment often appeared around the infected areas on both susceptible and resistant oat varieties. Miss Wheldale (8) called attention to the fact that this frequently occurs when plants are invaded by fungi.

Parker (3) places some importance upon the early production of telia on oat seedlings as a sign of resistance. He says, "It is certain that in the hundreds of seedlings described as very susceptible in the present experiments, telia were not produced on a single one following a normal and abundant production of uredinia." This does not agree with the observations of the writer. Although telia were produced on seedlings of some oat varieties resistant to crown rust, the same thing occurred frequently on susceptible forms. See table 2 for records of early formation of telia on both resistant and susceptible varieties and selections.

* Key to table 2 (see page 313):

0 = Immune: No uredinia; flecks and dead areas sometimes present; tissue at tip of plants often killed, browned or yellowed.

1 = Highly resistant: Infection weak; uredinia few and minute, generally surrounded by dead areas; tips of plants sometimes dead.

2 = Moderately resistant: Infection moderate; uredinia isolated and small to medium in size; hypersensitiveness of host common; uredinia sometimes in center of green islands.

3 = Moderately susceptible: Uredinia vary in size from that of a pin-head to about 1 mm. in diameter; otherwise infection normal. No hypersensitiveness.

4 = Completely susceptible: Infection very heavy; uredinia numerous, coalescent, and varying in size from 1 to 10 mm. by 0.5 to 2 mm. No hypersensitiveness.

This is the system used in the biologic form investigations being carried on cooperatively between the Minnesota Experiment Station and the United States Department of Agriculture.

† Telia developed on leaves.

TABLE 2*

Results of inoculating varieties and strains of oats with different strains of Puccinia coronata

PLACE OF COLLECTION OF RUST	HOST ON WHICH COLLECTED	CHARACTER OF INFECTION						
		Green Russian Iowa 96	Ruakura Rust Proof Iowa 73	White Russian Iowa 101½	White Russian Iowa 102½	Iowa 103 (Minnesota 531)	Iowa 115	Improved Lig-owa Minnesota 281
Burlington, Vt.	Rhamnus cathartica	1	0	3†	1†	4	3†	4†
St. Paul, Minn.	Rhamnus cathartica	4	1	4	3	4†	4	4†
Ames, Iowa	Avena sativa						4	4
Arlington, Va.	Avena sativa	2	2			4		4
Athens, Ga.	Avena sativa			2				4
Auburn, Ala.	Avena sativa	1	1			4	4	4
Beaumont, Tex.	Avena sativa			4		4		4
Brookings, S. D.	Avena sativa	4	2	4†	2	2	4	4†
Clemson College, S. C.	Avena sativa	4	4	4†	4	4	4	4
Columbus, Ohio	Avena sativa			3		3	4	4
Duluth, Minn.	Avena sativa	4†	3	4†	3†	4	3	4†
E. Lansing, Mich.	Avena sativa		2	4	4		4	4
Fargo, N. D.	Avena sativa	3		3	2	3	4	4
Ft. Collins, Colo.	Avena sativa				2	3	4	4
Jackson, Tenn.	Avena sativa	4	4	4	4	4	4	4
Knoxville, Tenn.	Avena sativa					4	4	4
Madison, Wis.	Avena sativa			2				4†
Marion, Ohio	Avena sativa	1†	3	4†	3	4	4	4†
Mendota, Minn.	Avena sativa	4†	1	4	4	4	3	4
St. Anne de Bellevue, P. Q., Can.	Avena sativa	2	4†	4†	4	4	4	4†
St. Louis, Mo.	Avena sativa	3		3	4	4	4	4
St. Paul, Minn.	Avena sativa	2†	2	2†	2†	2†	4	4†
San Augustine, Tex.	Avena sativa					4	3	4
Springfield, Mo.	Avena sativa						4	4
Tallulah, La.	Avena sativa	4†	4†	4†	3	4†	4†	4
Wabash, Ind.	Avena sativa			2		4	4	4
Waseca, Minn.	Avena sativa	4†	1†	3	3†	4	3	4
Washington, D. C.	Avena sativa	3†	1	4	3†	4	4	4†
Wellington, Ohio	Avena sativa	4	2	4	4	4	4	4
Winchester, W. Va.	Avena sativa	2	0	4	2	4	4	4
Wooster, Ohio	Avena sativa	4	2	4	4	4	4	4
St. Paul, Minn.	Avena sterilis					4†	2	4†

The results presented in this paper are significant, because they may throw some light on epidemiology studies and perhaps materially affect the problem of breeding oat varieties for resistance to crown rust. Should rust-resistant varieties be obtained in one locality where only certain biologic forms of rust are present, these same varieties may be entirely susceptible if sown in another locality where biologic forms capable of infecting them are present, although perhaps yet unrecognized. For example, the absence of crown rust in serious abundance in an oat growing section may not necessarily indicate that the oat varieties grown are rust-resistant, but merely that a biologic form of rust capable of infecting those varieties is not present. These apparently rust-free varieties may become heavily rusted if sown in a locality where there exists a biologic form of rust capable of infecting them. The breeding problem must therefore become local or regional.

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PLATE XIX

FIG. 1. Ruakura Rust Proof (Iowa 73) and Green Russian (Iowa 96) inoculated with *P. coronata* collected on oats at Clemson College, S. C. Both varieties were susceptible.

FIG. 2. Ruakura Rust Proof (Iowa 73) and Green Russian (Iowa 96) inoculated with *P. coronata* collected on *Rhamnus carthartica* L. at Burlington, Vt. Both varieties very resistant.

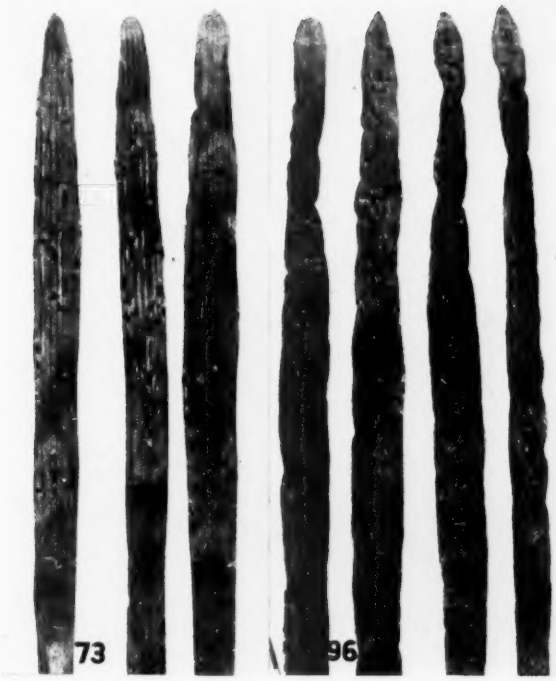

FIG. 1

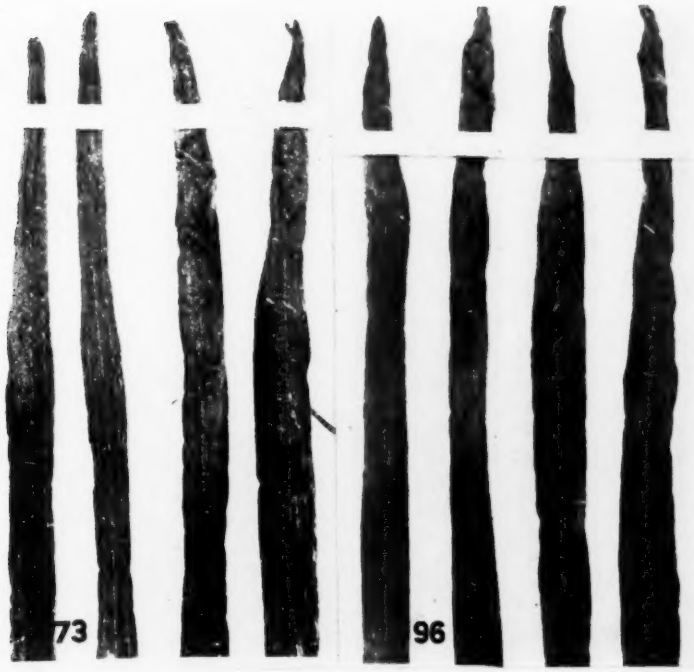

FIG. 2

HOERENR: PUCCINIA CORONATA ON OATS

Plate XX

Fig. 1. Ruakura Rust Proof (Iowa 73) and Green Russian (Iowa 96) inoculated with *P. coronate* collected on *Rhamnus cathartica* L. at St. Paul, Minn. Ruakura Rust Proof resistant; Green Russian susceptible.

Fig. 2. Ruakura Rust Proof (Iowa 73) and Green Russian (Iowa 96) inoculated with *P. coronata* collected on oats at Marion, Ohio. Ruakura Rust Proof moderately susceptible; Green Russian resistant.

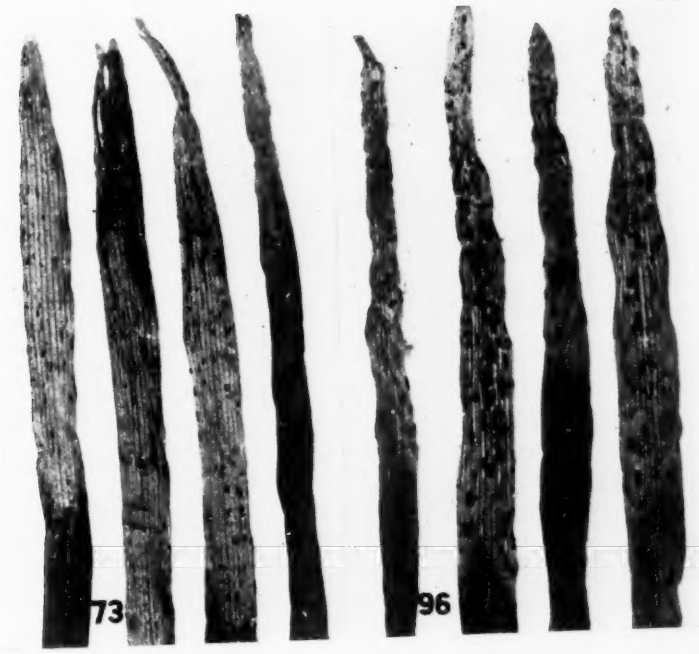

FIG. 1

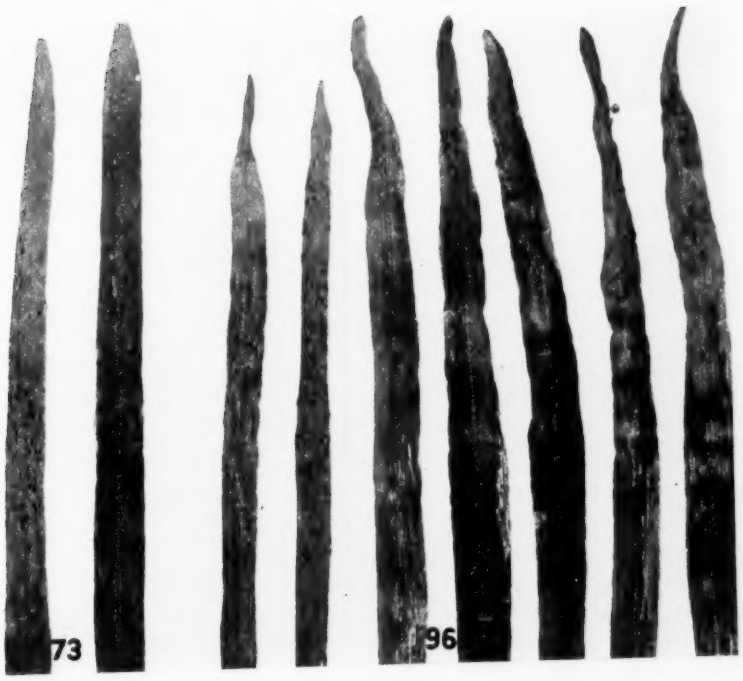

FIG. 2

HOERNER: PUCCINIA CORONATA ON OATS

PHYLLOSTICTA LEAF SPOT AND DAMPING OFF OF SNAPDRAGONS

E. F. Guba and P. J. Anderson

With Eight Figures in the Text

During the autumn of 1918 a leaf spot disease was prevalent among the cultivated snapdragons (*Antirrhinum majus* L.) in the perennial gardens of the Agricultural College at Amherst, Massachusetts. The spots were much larger and in other ways quite different from those produced by the anthracnose fungus (*Colletotrichum Antirrhini* Stew.). A search through the literature failed to show that a leaf spot of this character had previously been described or reported from America. In order to make further investigations, small "volunteer" plants which had started in the beds

Fig. 1. Leaf Lesions on Two Inoculated Plants

about the old ones were potted and brought into the greenhouse. They were watered frequently at first in order to get them well established in the pots, but after a week or two a number of them had damped-off and were lost. Examination of the damping-off lesions showed that this was only another symptom of the disease which had been found on the leaves. This led the writers to examine again the out of door plants and, although it was late in the season and the plants were frozen, stem lesions were discovered. They were usually connected with dead leaves, indicating that the disease had resulted from leaf or petiole lesions. Since the disease

appeared to be of some importance and is probably prevalent in other sections, the results of further studies are presented here.

Symptoms. On the leaves the disease manifests itself as large circular dark brown or black spots usually showing a series of concentric ridges which produce a target-board effect much like the lesions of the early blight of potato. The spots are typically about 1 cm. in diameter and

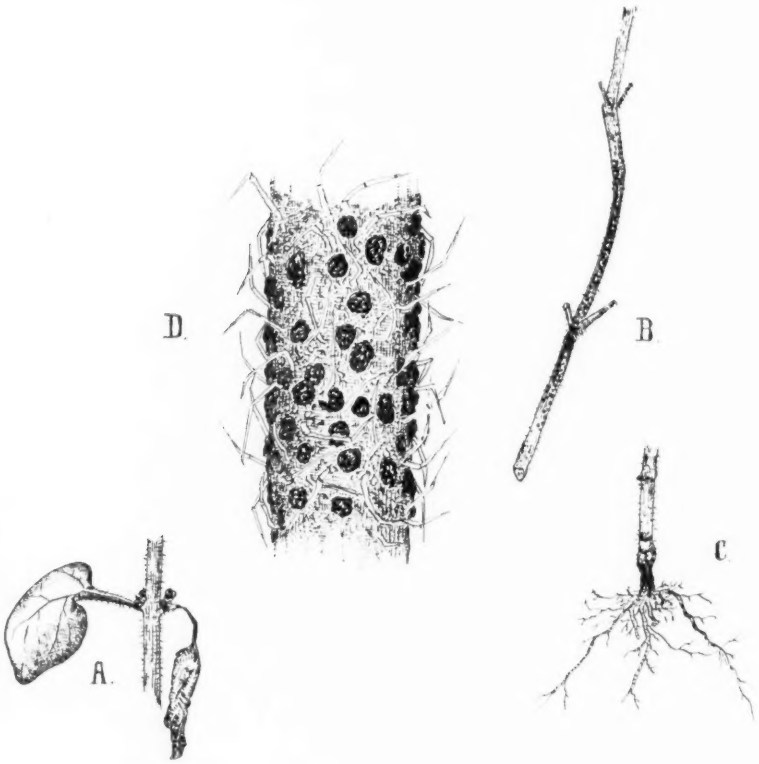

FIG. 2. *a*, PETIOLE LESION CAUSING DEATH OF THE LEAF; *b*, STEM LESION SHOWING CONSTRICTION: *c*, DAMPING-OFF LESION: *d*, ENLARGED SECTION OF A STEM LESION SHOWING PYCNIDIA

usually only one or two on a leaf but sometimes as many as five have been observed. When more than one spot occurs on a leaf, they usually merge and form large irregular blotches. They may be located on any part but show a preference for the tips and edges. Lesions on the edge of the leaf are at first elongated but later advance inward and become semi-circular. Under favorable conditions of moisture, the leaf spots do not

appear to be determinate but continue to spread until the entire leaf is involved.

The spots begin as small yellow unglazed areas as distinguished from the glossy green of the healthy tissue, accompanied by shrivelling and depression. The center of the spot, or starting point of infection, gradually becomes yellow-brown and transparent, revealing the venation of the leaf when wet. The yellow-brown then alternates outwardly with concentric rings of darker brown. A hand lens shows numerous tiny dark points associated with the darker rings or scattered sometimes irregularly over the surface of the spot. Leaves attacked when young become distorted

FIG. 3. PLANT AFFECTED BY DAMPING-OFF COMPARED WITH A HEALTHY ONE

and curled (fig. 1), and if the attack is severe the whole leaf shrivels and dies but remains clinging to the stem. Lesions become dry, hard and brittle, readily breaking to pieces when handled.

Brown elongated lesions occur on the petioles. The petiole is quickly girdled and the leaf droops and dies (fig. 2, a). Almost invariably also the petiole lesions spread downward and result in stem infections at the axils of the leaves.

The stem lesions are dark green or brown, without definite margins and may extend along one side for 2 or 3 cm. before the stem is girdled. The lesions then become dark and constricted and dotted over with numerous black points like those on the leaves (fig. 2, *b* and *d*). The stem usually

bends over at the point of attack. Soon all parts above die and become brittle, hard and dry.

The first noticeable symptom of damping-off is the rather rapid wilting and dying of all parts above ground (fig. 3). Examination of the base of the stem reveals the characteristic brown-black lesion considerably constricted and beset with the same numerous black specks (fig. 2, *c*).

Isolation. Microscopic examination showed the small black specks scattered over the lesions to be pycnidia. Isolations were made by transferring small bits of the diseased tissue to potato agar slants after the surface of the lesion had been sterilized with mercuric chloride (1–1000) and washed with sterile water. Some difficulty was at first encountered in

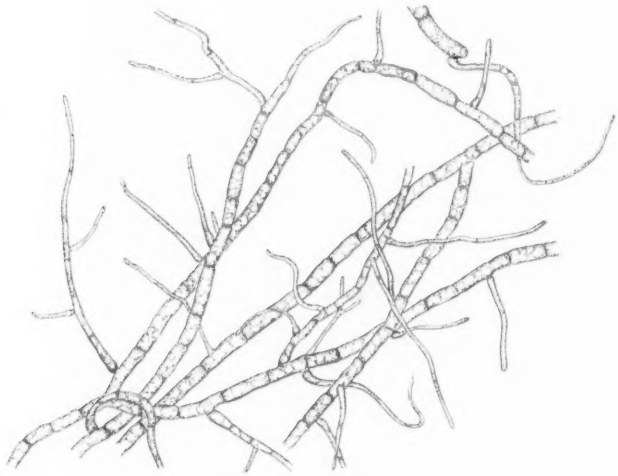

FIG. 4. MYCELIUM FROM CULTURE

securing the pycnidial form in pure culture because of an Alternaria which was usually present on the lesions and which grew in culture more rapidly than the other fungus. The Alternaria was also kept in pure culture with the expectation of testing out its pathogenicity, but since—as is shown below—the pycnidial form alone was able to produce the disease, it was concluded that the Alternaria was secondary and no further attention was given it.

At an incubating temperature of 28°C. growth becomes perceptible on the agar within twenty-four hours. At the end of four days one half of the surface of the slant is covered with a rather thin, flat growth and pycnidia are visible. They are most numerous about the center of the growth but never so thick as to give it a solid black appearance. They are at first of a yellow brown color but become dark with age. As the

culture becomes older, radiating streaks of dark brown develop, extending outward toward the periphery. Sometimes the whole culture takes on this dark color. The pycnidia develop most numerously along these dark streaks. The characters and measurements of pycnidia and spores in culture were found to be identical with those of the fungus on the leaves.

Mycelium. The characters of the mycelium in culture and in the host appear to be the same. The black streaks in the cultures at first give one the impression of a mixed culture, but microscopic examination and further culturing prove that such is not the explanation. The hyphae are at first hyaline but in the streaks they become brown and the walls are thicker. The thallus is composed of large stout main branches which may or may not take on the brown color, and much smaller lateral branches which diverge at acute or right angles from the stouter ones (fig. 4). The stout hyphae

FIG. 5. ENLARGED LEAF SPOT SHOWING PYCNIDIA

are rather closely septate forming cells $1\frac{1}{2}$ to 2 times as long as broad and are constricted at the septa. The lateral branches are hyaline, more distantly septate and not constricted at the septa. In the host the mycelium is intercellular.

Pycnidia. The pycnidia develop directly under the epidermis. With age the epidermis is pushed up and is finally ruptured by the ostiole. The ostiolate end of the pycnidia may emerge from either side of the lesion: rarely, however, from the lower side. The pycnidia are very prominent, and distinctly visible from the upper side (fig. 5). They can also be seen from the lower side due to the transparency of the lesion which occurs quite frequently, especially when the lesions are wet. They show no differences in culture and on the host. They are globose and range in diameter from 78 to 152μ with an average of 108μ. The ostiole is papilliform and round. The wall is at first light yellow brown but becomes

darker with age. The wall of the pycnidium is very thin, consisting usually of only two layers of thin tabular cells (fig. 6). The cell walls of the outer layer are thicker and impart the dark color to the pycnidium. Seen in face view they are irregularly hexagonal and of a diameter of 10 to 12μ (fig. 7). The conidiophores have not been seen. If present they must be very short and inconspicuous. The interior of the pycnidium is densely packed with spores which issue from the ostiole in long gelatinous cirrhi. When the pycnidia are mounted in water, these rope-like strands may be watched for twenty minutes or more pushing out of the ostiole and remaining for a long time in regular formation (fig. 7).

Spores. The spores are continuous, hyaline, oblong or oval to elongate, straight, with homogeneous contents. Spores from the host measured

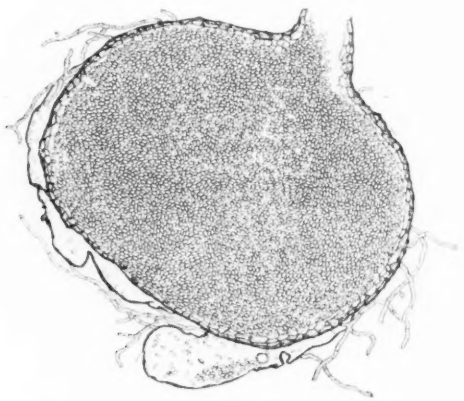

FIG. 6. LONGISECTION OF A PYCNIDIUM

3.1 to 4.27 by 1.5 to 2.1 (average 3.8 by 1.9μ). In culture they averaged 4.2 by 2μ (fig. 8, *a*).

Germination of spores. Immersed in a drop of water in a Petri dish and kept at ordinary laboratory temperature, the spores germinate in sixteen to thirty hours. Germination is accompanied by a great increase in size of the spores, the average after thirty-six hours being 10 by 7μ. One, two, or three germ tubes may arise from a single spore but the usual number is two (fig. 8, *b*). The tubes are commonly polar. They quickly become septate and branched. Anastomosing of the branches from the same spore or from different spores is very common. Germination seemed to be best at about 25°C. but no extensive determinations were made of the optimum, maximum and minimum. They are not killed by exposure to winter temperatures. Pycnospores from plants which had been out

of doors all winter were used for infection experiments during February and produced the disease as readily as spores from fresh cultures.

Infection experiments. Healthy plants which had been growing for two months in the greenhouse were used for infection experiments. Pycnidia from pure culture were crushed in sterile water and the spore suspension thus obtained was sprayed over the plants with an atomizer. The sprayed plants were covered for several days with bell jars. Throughout the entire set of experiments, the lesions seldom became visible before nine days but developed very rapidly after they started. In order to see whether wounds are necessary, the leaves of two plants were punctured

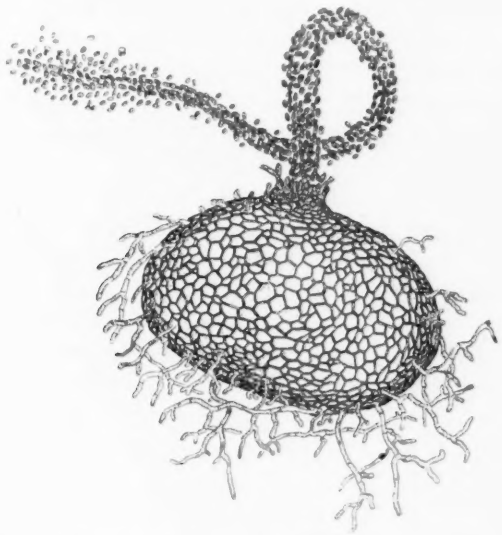

FIG. 7. DETACHED PYCNIDIUM WITH EXUDING SPORES

by numerous stabs of a sterile needle. Two others were not injured and all four were sprayed with spores at the same time and kept under the same conditions. Lesions became apparent on the stabbed leaves within five days. On the uninjured leaves they were not seen until the ninth day. Also they were not so numerous as on the stabbed leaves. Wounds then do not seem to be necessary for infection but, on the other hand, they do furnish good infection courts. Since they were not necessary, none of the plants in numerous subsequent experiments were wounded but infections invariably resulted. In another set of experiments, bits of agar from pure cultures containing mycelium and spores were applied to the leaves without wounding them. Lesions always became apparent about the points of application within nine days while the checks remained healthy.

Pycnidia begin to appear on the fourth or fifth day after the lesion appears, first a few on the yellow-brown center of the spot and then later more numerously on the concentric darker zones but in old spots they may be scattered irregularly over the entire surface.

The effect of moisture conditions of atmosphere and soil is very marked. When the plants are kept continuously in a moist atmosphere such as may be secured by placing them in an enclosed chamber, the disease continues to spread until eventually the entire plant is killed. But, if the atmosphere is dry and the plants are not heavily watered, the lesions may cease

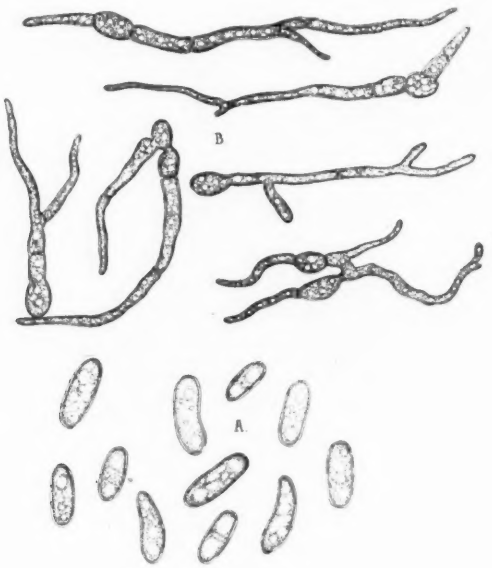

FIG. 8. *a*, PYCNOSPORES; *b*, GERMINATING PYCNOSPORES

to spread altogether or grow only very slowly. The damping-off type is especially favored when the soil is kept in a very moist condition.

Reisolation. Isolations were made from the spots which had been produced by inoculation of leaves and stems. A fungus was secured in pure culture which in all characters was like the one which had originally been isolated from the plants in the perennial gardens. The pathogenicity of this fungus has thus been established by (1) finding it constantly associated with the disease, (2) isolating and studying it in pure culture, (3) producing the disease on previously healthy plants by inoculating with spores from pure culture while the checks remained healthy and (4) reisolating the fungus from the inoculated plants and proving from morphological

and cultural characters that it was identical with the fungus originally isolated.

Identity of the causal fungus. The globose, ostiolate, dark-colored, thin-walled pycnidia situated beneath the epidermis in definite leaf spots, and the ovate or elongate, continuous, hyaline spores locate this species at once in the genus Phyllosticta. Turning to the literature we find that only one species of Phyllosticta has been reported on this host, *Phyllosticta Antirrhini* Syd., which was described[1] from plants in Berlin, Germany, as follows:

"*Phyllosticta Antirrhini* sp. n. Maculis amphigenis, in epiphyllo pallescentibus, in hypophyllo virescentibus, plerumque marginalibus, v. apicalibus, usque 1 cm. longis, definitis, interdum subzonatis; peritheciis epiphyllis, minutis, globosis, ca. 100–180μ diam., sparsis v. subgregariis, atrobruneis; sporulis oblongis, continuis, hyalinis, eguttulatis, 4–6 x 1½–2.

"Hab. in foliis Antirrhini spec., pr. Berolinum, Germaniae."

No other reference to the leaf-inhabiting fungus has been found by the writers in European or American literature. No European material has been examined but the description and measurements correspond rather closely with those of the fungus as found here. There appears to be no good reason for believing the two to be distinct.

When, however, the same fungus was found on the stems, the possibility was suggested that it had been described as a Phoma. The artificial basis of classification, by which all such fungi as this inhabiting leaf spots are called Phyllosticta while those on other parts of the plant are called Phoma, does not offer a satisfactory method of classifying those which occur on both stem and leaf. A Phoma stem rot of snapdragons was described by Stewart[2] from New York in 1900. He found that this fungus girdled the succulent stems and caused the tips to die. He isolated it and was able to produce the disease by inoculation. Spore measurements are given as 4 to 5 by 2μ and it is stated that the spores issue from the ostiolum in colorless, gelatinous, rope-like masses. No specific name was given to this Phoma. Professor Stewart kindly furnished dried specimens for the writers to examine and they were unable to find any essential difference between it and the Phyllosticta under investigation. Professor Stewart also is of the opinion[3] that the two may be identical.

In short then it seems that the large leaf spot, the damping-off and the stem rot are caused by the same fungus and may be considered as

[1] Sydow, P. Beitrage zur Kenntniss der Pilzflora der Mark Brandenburg II. Beitblatt zur Hedwigia **38**: (134). 1899. Same in Sacc. Syll. **16**: 839. 1902.

[2] Stewart, F. C. An anthracnose and stem rot of the cultivated snapdragon. N. Y. (Geneva) Agr. Exp. Sta. Bul. 179. 1900.

[3] Private correspondence with the senior writer.

only different symptoms of the same disease. Since the organism was originally described as a Phyllosticta and does cause a definite leaf spot, it will undoubtedly be best to retain the name *Phyllosticta Antirrhini* Syd. even though it does infest the stem also.

Control. Stewart suggests spraying the plants with Bordeaux mixture as for anthracnose but his suggestion was apparently not based on experiments with this particular fungus. The efficiency of a few common fungicides was determined by the present writers in the laboratory. By means of an atomizer, glass slides were sprayed with (a) Bordeaux mixture 4–4–50, (b) ammoniacal copper carbonate, (c) lime-sulphur 1–30, 1–40 and 1–50 and permitted to dry for one or more days. A drop of water containing fresh spores of the fungus was placed on the center of the sprayed surface of each slide and the slides kept in Petri dishes to prevent evaporation of the water. Similarly, drops of the spore suspension were placed on unsprayed slides for checks. Percentages of germination were counted after seventy-two hours. The average results of five series are as follows:

Fungicide used	*Percentage of germination*
Lime-Sulphur, (1–30)	27
Lime-Sulphur (1–40)	27
Lime-sulpuhr (1–50)	22
Bordeaux mixture	0
Ammoniacal copper carbonate	37
Checks	86

Results with the lime-sulphur were puzzling and not constant, but indicate without question that this fungicide is not efficient at the strengths tested. Bordeaux mixture alone gave satisfactory results and was, therefore, employed in the control experiments on the plants in the green house.

On February 5 four plants were inoculated with a spore suspension in the manner already described. Three of these plants were sprayed with standard Bordeaux mixture previous to inoculation. Lesions began to appear on the unsprayed plants on the ninth day after inoculation and by March 6 most of the leaves were affected and many of them dead. Plants sprayed with Bordeaux showed no lesions whatever.

On February 19th, five more plants were inoculated, three of which were previously sprayed with Bordeaux mixture. By March 7, 50 per cent of the leaves of the unsprayed plants were either dead or badly affected while those of the sprayed plants were perfectly healthy. One of the sprayed plants, however, succumbed to a damping off lesion on March 5.

These experiments indicate that all types of this disease with the exception of damping-off can be controlled by spraying with Bordeaux

mixture 4–4–50. In the case of damping-off the fungus enters the plant at a point below the surface of the soil and spraying is obviously not to be depended on. It seems likely that the pathogen lives in the soil. If damping-off should prove to be serious, soil sterilization of the seed bed with formaldehyde or steam should be efficient. Succulent shoots are very susceptible to the fungus whereas the woody stems are not so easily affected. In checking the disease it is very essential that the air and soil be kept as dry as is consistant with good growing conditions for the plants.

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BRIEFER ARTICLES

SEED TRANSMISSION OF CUCURBIT MOSAIC BY THE WILD CUCUMBER

S. P. Doolittle and W. W. Gilbert

It has already been demonstrated by the writers (1918) that the wild cucumber, *Micrampelis* (*Echinocystis*) *lobata*, is susceptible to cucurbit mosaic and that the disease often appears on the wild host from three to four weeks before it occurs on cucumbers in the field. These facts, coupled with the common occurrence of the wild cucumber in the pickle growing districts of the Central States, are of considerable importance in relation to the overwintering of the disease.

Observations during the spring of 1918 showed that the disease again appeared on the wild plants in the same spots in which it had been found the previous year. Several such centers were found by the writers in Michigan and Wisconsin and in all cases represented the first appearance of the disease observed on any cucurbit host in the respective localities. Since soil has been practically eliminated as a source of mosaic overwintering and infection, trials were made to determine the possibility of the disease being carried over winter in the seed from mosaic plants. An earlier trial of such seed, made during the winter of 1917–18, had given negative results, but the conditions were such that the plants did not make a normal growth and the test was not satisfactory.

During the fall of 1918 seed was again collected from mosaic wild cucumber plants at Big Rapids, Michigan. About twenty plants grown from this seed in the Washington greenhouses during the winter of 1918–19 failed to show any mosaic symptoms. Another portion of the seed was grown in the greenhouses of the University Department of Plant Pathology at Madison, Wisconsin. The seed was planted in sterilized soil in a house which was isolated from other cucurbits and was practically free from insects of all kinds. The planting was made on April 9, 1919, and 110 plants were secured from the seed. On April 25 the seedlings were examined and a peculiar yellow mottling was noted on the first true leaves of thirteen individuals. These plants were marked and kept under observation until May 15, the symptoms becoming more definitely mosaic in character as the plants grew older. On this date cross inoculations were made to healthy plants of Micrampelis from the suspected cases of mosaic, three plants being inoculated from each of the suspects.

The inoculations were made by inserting a small fragment of crushed leaf tissue from the suspected plant into a slight incision in the stem of the plant inoculated. This cut was made just below the first leaf, using a sterile scalpel. Thirty check plants were treated in the same manner except that the leaf tissue of a healthy plant was inserted in the stem. The inoculated plants were examined on May 22 and the inoculations from ten out of thirteen of the suspects were found to have produced positive cases of mosaic in twenty-one out of thirty of the plants inoculated from these sources. All check plants remained healthy.

The chance for outside infection in the experiment noted above was so small as to be negligible, and the fact that the symptoms were noted in the first leaves makes it very probable that the disease was carried in the seed. This probability is strengthened by the fact that the inoculation of seeds of the wild cucumber with mosaic shortly after they began to germinate has produced early symptoms identical with those noted on plants grown from mosaic seed.

It is therefore possible that a certain percentage of the seed from mosaic plants of the wild cucumber, *Micrampelis lobata*, may produce diseased plants the following season. In this way the first mosaic centers are established, from which the disease is later carried to the cultivated cucumber in nearby fields by the striped cucumber beetles or other insects.

Bureau of Plant Industry
U. S. Department of Agriculture

NOMENCLATURE OF THE POTATO SCAB ORGANISM

H. H. McKinney

The taxonomy and nomenclature, as well as the ideas concerning the natural distribution of the causal organism of potato scab, were upset when Cunningham (3), 1912, placed the organism among the higher bacteria. Güssow (5), 1914, accepted this classification and considered Actinomyces the proper generic name. Later Lutman and Cunningham (7), 1914, identified it as *Actinomyces chromogenus* Gasp. and advanced the theory that it "is a widespread organism, which is found in practically all soils, so far as known. . . . "

Workers who have studied the scab organism recently seem to agree that it is congeneric with the species included in the genus Actinomyces Harz, as described by Chester (1), 1900, under the generic term Streptothrix Cohn and by Saccardo (8), 1889, as Nocardia Trev. However, the taxonomic position of this genus has for some time been a matter of considerable doubt. Sauvageau and Radais (9), 1892, considered the genus among the Hyphomycetes and this view was accepted by a few bacteriol-

ogists, but the majority of bacteriologists have classed it among the bacteria or assigned it to a position between the bacteria and the fungi.

Much work has been published relative to the phylogenetic position of the genus Actinomyces, but in practically all cases there seems to be a lack of thoroughness in the work done on this subject, as evidenced by the indefinite illustrations which are supposed to characterize the morphology of the various members of this genus.

Drechsler (4), 1919, made detailed morphological studies of eighteen members of the genus and he has supported his descriptions with highly detailed drawings. He has demonstrated quite clearly that the genus does not belong with the Schizomycetes, but rather with the Hyphomycetes in the family Mucedinaceae.

The writer, working in the plant pathology laboratory of the University of Wisconsin, has studied three strains of the scab organism isolated from scabby potatoes grown in three localities in this state, all of which are pathogenic upon growing tubers and produce the brown diffusible pigment upon gelatin and agar media. While there is some slight variation in the virulence and in pigment formation, the morphology of these organisms is identical with that of the scab fungus as described by Drechsler.

It is known that brown pigment forming Actinomyces species are quite widely distributed throughout soil, and in the past these forms were identified with *Actinomyces chromogenus* Gasp. on account of the pigment character. When we consider the works of Krainsky (6), 1914, Waksman and Curtis (10), 1916, and Drechsler (4), 1919, it is quite evident that this character cannot be considered specific. These workers have demonstrated that *Actinomyces chromogenus* is merely a group of numerous species differing in physiology and morphology. Therefore, data concerning the natural distribution of such a group do not necessarily apply to the scab fungus or to any other single species within the group, and consequently, due to the lack of supporting evidence, Lutman and Cunningham's theory concerning the universal distribution of the scab fungus must be abandoned.

In view of the above works it is plainly impossible, as pointed out by Conn (2), 1916, and Drechsler (4), 1919, to apply the binomial *Actinomyces chromogenus* Gasp. to the scab organism, and in consideration of all these facts the writer maintains with Drechsler that the binomial *Actinomyces scabies* (Thax.) Güssow should be accepted as the name of the organism which causes common scab of the potato tuber.

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PHYTOPATHOLOGICAL NOTES

Puccinia antirrhini. Peltier and Rees[1] have reported *Puccinia antirrhini* D. & H. as doing considerable damage in the vicinity of Chicago in 1913–14. Clinton[2] has also reported it from Connecticut. In December, 1918, it was found in the greenhouse of the Horticulture Department at the University of Nebraska. Inquiry among greenhouse men and florists of the state disclosed the fact that several of them had first noticed the rust in 1916–1917, and it has now been reported by practically every grower of snapdragons in the state, as well as by growers from Council Bluffs, Iowa, and St. Joseph, Missouri. In several of the larger greenhouses throughout the state the growing of snapdragons has been all but abandoned because of the trouble with rust. In some houses from 25 to 50 per cent of the plants have been killed. Infection apparently takes place in the field, and the rust is brought into the house with the plants in the fall. The uredospore stage is the only one that has been seen. Pustules appear in abundance on the leaves and stems of young seedlings, cuttings, or mature plants. On the leaves the sori usually appear first on the lower surface, but later they may appear on the upper surface as well. There is usually a marked zonation, and leaves severely infected turn brown in spots and often drop off. The plants affected are often badly stunted and do not produce flowers until very late in the season or not at all. It seems probable that this rust was introduced into the state on cuttings from some infected region, but efforts to trace it to some such source have so far been unsuccessful.

H. W. Thurston, Jr.

St. Louis Conference on take-all and flag smut of wheat. A meeting of plant pathologists from the central and eastern grain-growing states was called for May 12, 1919, at St. Louis, Missouri, by the Plant Disease Survey and the Office of Cereal Investigations. The purpose of the meeting was to acquaint these men with the field characteristics of two serious diseases of wheat new to America, in order that they might be better able to determine whether the diseases occur in their respective states. These

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[2] Clinton, G. P. Notes on plant diseases of Connecticut. Connecticut Agr. Expt. Sta. Rpt. **1915**: 443: 444. 1916.

diseases are flag-smut and take-all, recently discovered near Granite City, Madison County, Illinois.

An informal meeting was held at 9.00 a.m., May 12, at the Jefferson Hotel, and at 10.00 a. m. the whole party was taken by auto to two fields near Granite City, where the diseases were studied. The party then inspected other fields in Madison County, in order to see the disease in various stages of development.

A summary by A. G. Johnson of the situation in southern Illinois follows:

The diseased condition of the wheat was first reported to the Secretary of Agriculture about the middle of April by county agricultural agent J. B. Haberkorn, of Madison County, Illinois. The report was referred to the Office of Cereal Investigations, Bureau of Plant Industry. Dr. Johnson went into the state and conferred with Dr. W. L. Burlison and G. H. Dungan of the Illinois Agricultural Experiment Station on April 20. On the following day he visited and carefully examined several of the infested fields. After careful study he decided that the trouble was the Australian "take-all" disease or something very similar to it. It therefore seemed practically certain that the trouble in Illinois was the Australian "take-all."

Mr. H. H. McKinney was detailed to conduct investigational work on the disease. Mr. C. S. Reddy and a group of men made a survey of the region to determine the geographic range and the destructiveness of the disease. The following is a general summary of results:

Number of fields surveyed	121
Approximate number of acres	4,267
Number of fields infested with take-all	32
Approximate number of acres	802
Number of fields infested with flag smut	23
Approximate number of acres	554
Number of fields with both take-all and flag smut	10
Approximate number of acres	269

During the trip of May 5 flag smut was discovered by Mr. J. G. Dickson in one of the fields. As indicated above, it has been found since that time in 33 fields. In most fields only a slight infection was noted, while in others it ran as high as 1 to 2 per cent, at least in certain places in the fields.

The manifestations of "take-all" vary considerably in different fields according to the severity of the attacks. In some fields distinct patches of varying size occur, in which the badly diseased plants are greatly dwarfed; in fact, remain in the rosette stage while surrounding plants are more than knee high. Such plants, if still alive, show a characteristic bluish-green color in striking contrast to the normal green of healthy

wheat. These patches may be only a few feet in diameter or up to 70 feet or more, and the outlines may also vary greatly. In a few fields scarcely any patches are evident, since the infection becomes rather general over the entire field.

In the badly infested fields many of the dwarfed plants are entirely killed and are dried up and brown, leaving patches entirely bare. Some of the dwarfed plants have rather wide rosette leaves, while those that are more severely infected and not yet entirely killed, in an attempt at recovery, shoot up a number of new supplementary sprouts. These are, naturally, very weak and as a result their leaves are very narrow and more or less grass-like. The characteristics of this dwarfed rosette stage are very striking.

G. M. Reed has briefly summarized the flag smut situation. Flag smut is a serious disease in some sections of Australia, and is also reported from Japan and India. In Australia it frequently causes 5 to 10 per cent destruction of the crop. Occasionally it is much more severe.

This is a typical leaf smut and becomes evident soon after the plant begins to send up the stalks. The upper leaves become more or less twisted and dark lines appears, extending lengthwise of the leaves. These soon break open and allow the spores to escape. The affected leaves later split into longitudinal shreds.

Frequently the smutted plants are stunted. Rarely do they develop sufficiently to form heads. When heads are formed they rarely produce seed.

Resolutions setting forth, (1) the seriousness of the situation, (2) the urgent need for immediate steps to determine the present geographical distribution of these diseases, and (3) the necessity of an adequately onganised Plant Disease Survey to obtain data on these and similarly destructive plant diseases, were drawn and adopted.

Announcement was made of the Summer Conference of Cereal Pathologists at St. Louis, June 5, 6 and 7, 1919.

The meeting adjourned at 11.15 p.m.

W. G. STOVER,
Secretary.

G. R. COONS,
President.

Personals: Dr. R. O. Cromwell of the Bureau of Plant Industry, who has recently been engaged in extension work on the control of truck crop diseases in Iowa, has been transferred to survey work on the distribution of wheat scab.

Miss Helen Johann, formerly research assistant in plant pathology at the Missouri Agricultural Experiment Station, has accepted a position in the U. S. Department of Agriculture in connection with investigations of wheat scab and the related Fusarium rots of cereals. She will be located at the Wisconsin Agricultural Experiment Station.

Dr. F. A. Wolf has returned to his former position as botanist and plant pathologist of the North Carolina Agricultural Experiment Station.

Dr. L. M. Massey, who has been employed by the Department of Agriculture as extension pathologist in New Jersey during the past year, has returned to Cornell University to resume his investigational work on the diseases of florists' crops.

Mr. J. W. Blachly and Mr. E. C. Sherwood of the Bureau of Plant Industry, formerly extension pathologist in Kansas and Oklahoma, respectively, have been transferred to the Plant Disease Survey.

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COMPILED BY ALICE C. ATWOOD AND FLORENCE P. SMITH, BIBLIOGRAPHICAL ASSISTANTS, BUREAU OF PLANT INDUSTRY

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[PHYTOPATHOLOGY for July, 1919 (**9:** 275–308, pl. XVIII) was issued July 29, 1919.]